

Short Range-Ordered Minerals: Insight into Aqueous Alteration Processes on Mars

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Short range-ordered (SRO) aluminosilicates (e.g., allophane) and nanophase ferric oxides (npOx) are common SRO minerals derived during aqueous alteration of basaltic materials. NpOx refers to poorly crystalline or amorphous alteration products that can be any combination of superparamagnetic hematite and/or goethite, akaganeite, schwertmannite, ferrihydrite, iddingsite, and nanometer-sized ferric oxide particles that pigment palagonitic tephra.

Nearly 30 years ago, SRO phases were suggested as alteration phases on Mars based on similar spectral properties for altered basaltic tephra on the slopes of Mauna Kea in Hawaii and Martian bright regions measured by Earth-based telescopes. Detailed characterization of altered basaltic tephra on Mauna Kea have identified a variety of alteration phases including allophane, npOx, hisingerite, jarosite, alunite, hematite, goethite, ferrihydrite, halloysite, kaolinite, smectite, and zeolites. The presence of npOx and other Fe-bearing minerals (jarosite, hematite, goethite) was confirmed by the Mössbauer Spectrometer onboard the Mars Exploration Rovers. Although the presence of allophane has not been definitely identified on Mars robotic missions, chemical analysis by the Spirit and Opportunity rovers and thermal infrared spectral orbital measurements suggest the presence of allophane or allophane-like phases on Mars.

SRO phases form under a variety of environmental conditions on Earth ranging from cold and arid to warm and humid, including hydrothermal conditions. The formation of SRO aluminosilicates such as allophane (and crystalline halloysite) from basaltic material is controlled by several key factors including activity of water, extent of leaching, Si activity in solution, and available Al. Generally, a low leaching index (e.g., wet-dry cycles) and slightly acidic to alkaline conditions are necessary. NpOx generally form under aqueous oxidative weathering conditions, although thermal oxidative alteration may occasionally be involved. The style of aqueous alteration (hydrolytic vs. acid sulfate) impacts which phases will form (e.g., oxides, oxysulfates, and oxyhydroxides). Knowledge on the formation processes of SRO phases in basaltic materials on Earth has allowed significant enhancement in our understanding of the aqueous processes at work on Mars.

The 2011 Mars Science Laboratory (MSL) will provide an instrument suite that should improve our understanding of the mineralogical and chemical compositions of SRO phases. CheMin is an X-ray diffraction instrument that may provide broad X-ray diffraction peaks for SRO phases; e.g., broad peaks around 0.33 and 0.23 nm for allophane. Sample Analysis at Mars (SAM) heats samples and detects evolved gases of volatile-bearing phases including SRO phases (i.e., carbonates, sulfates, hydrated minerals). The Alpha Particle X-ray Spectrometer (APXS) and ChemCam element analyzers will provide chemical characterization of samples. The identification of SRO phases in surface materials on MSL will be challenging due to their nanocrystalline properties; their detection and identification will require utilizing the MSL instrument suite in concert. Ultimately, sample return missions will be required to definitively identify and fully characterize SRO minerals with state-of-the-art laboratory instrumentation back on Earth.